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RESEARCH ARTICLE

Ruffe (*Gymnocephalus cernuus* L.) growth and diet in Lake Dusia (southern Lithuania)

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Abstract. The ruffe, *Gymnocephalus cernuus* (L.), is considered to be a food competitor with many commercially valuable fishes such as bream, *Abramis brama* (L.), roach, *Rutilus rutilus* (L.), pikeperch, *Sander lucioperca* (L.), and perch, *Perca fluviatilis* L. This paper presents the results of an investigation into the fish community structure of Lake Dusia and the population parameters (morphometry, age, growth, diet) of ruffe as one of the prevailing fish species in the lake. The fish community of Lake Dusia was dominated by ruffe, perch, and roach. The ruffe population constituted 64.1% of the fish community of the lake in relative abundance and 36.8% in biomass. An analysis of the ruffe diet revealed that Gammaridae and Chironomidae were the principal components in all age-classes. The ruffe population was comprised mainly of individuals 3+ and 4+ years of age. The mean total length (TL) of ruffe was 13.39 ± 1.79 cm (minimum-maximum: 6.12-19.93 cm). The growth in length calculated using the von Bertalanffy equation was $L_t = 21.3[1-e^{-0.161(t-0.335)}]$. Ruffe growth rates were found to slow as the fish aged. Ruffe growth variations were linked to population density, fish community structure in the water body, abundance of invertebrates (zooplankton and zoobenthos), and type of water body.

Keywords: fish diet, growth, age, community, population

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Introduction

The natural range of ruffe, *Gymnocephalus cernuus* (L.), extends over Europe and Asia, and currently the species is spreading to North America and some still uninhabited water bodies in Europe. Ruffe can adapt to a variety of conditions, including fresh and salt waters, inhabiting depths of 0.25-85 m in mountainous and sub-mountainous zones and in oligotrophic and eutrophic water bodies (Bergman and Greenberg 1994). Ruffe development rates depend on gender, morphological type, water body type, intraspecific density, and quantities of available food (Ogle and Winfield 2009). The ruffe diet is rather diverse, although adults mainly feed on chironomid (*Chironomus* sp.) larvae (Tarvainen et al. 2008). Interactions with other fish species are manifested through food competition and predation (Ogle 1998). From an ecological viewpoint, the ruffe is a benthophagous benthic species with a short life cycle, early maturity, and a batch spawning reproductive strategy (Virbickas 2000). Several possible hypotheses could explain the positive relationship between eutrophication and ruffe abundance. First, ruffe forage more efficiently under reduced light conditions associated with increased algal production (Johansson and Persson 1986, Bergman 1991). Second, the benthos can increase in abundance and diversity and shift to smaller species in response to the storage of increased energy in sediments from eutrophication (Leach et al. 1977). Benthivorous ruffe might be favored by increased production and a shift to smaller species. Third, increased productivity could release predation pressure on ruffe (Bergman 1991). Fourth, ruffe may be physiologically more tolerant of eutrophic conditions than other percids (Ogle 1998).

Ruffe females reach 11 years of age, while males rarely live to the age of seven (Ogle 1998). Some authors report that ruffe can reach ages of 11-12 (Mills and Eloranta 1985, Jamet and Desmolles 1994). Ruffe total length (TL) is generally less than 20 cm, but it occasionally reaches 25 cm or even 29 cm (Lelek 1987, Ogle 1998). Ruffe grows very slowly, and the highest growth rates are recorded in the first and second years of life. According to many authors, ruffe growth rates largely depend on fish sex, water quality, density of individuals, and food availability. The growth of ruffe females inhabiting fresh waters is slower than that of males from marine water bodies (Lelek 1987). Slow growth rates might be indicative of small quantities of benthic organisms or oxygen deficits (Ogle 1998). The main components of ruffe diet are rotifers (Rotifera), copepods (Copepoda), and cladocerans (Cladocera) and chironomid larvae (Chironomidae), and these prey constitute the principal diet of young ruffe (Ogle 1998).

Lake Dusia hosts an abundant ruffe population that congregates at different sites in the lake depending on the season of the year and food availability. In the second half of summer and in fall, the greatest abundance of ruffe is observed in open, medium-depth waters rich in suitable food. In spring, shoals of mature ruffe migrate from their wintering sites closer to the shore and congregate en masse in the shallow littoral zone (Bubinas and Bukelskis 1998).

Investigations of ruffe and its diet in Lake Dusia are very important, because the population of this species is abundant there, and it is a food competitor of commercially-valuable fishes. Ruffe can prey on the spawn of other fish species and invertebrates preyed on by other fishes (Sierszen et al. 1996, Ogle 1998). Therefore, ruffe might have a detrimental effect on other fish species. The population of vendace in Lake Dusia has decreased drastically since 2001, and commercial fishing of this species is forbidden. According to the results of investigations conducted in Lake Dusia in 2012, the abundance of lake smelt, *Osmerus eperlanus* (L.), was 1033 ind. ha^{-1}, whereas that of ruffe was merely 400 ind. ha^{-1} with biomasses of 14.9 kg ha^{-1} and 1.8 kg ha^{-1}, respectively. Perch is the biological regulator of ruffe as its principal predator. However, it is unknown how ruffe affect the trophic links of the fish inhabiting the lake, which is why it is important to identify the dietary overlap between ruffe and other fish species. The purpose of our work was to investigate the ruffe population structure and foraging seasonality in Lake Dusia and to assess the impact ruffe has on other species in the fish community of the lake.

Study area and methods

Lake Dusia is situated approximately 5 km south of the town of Simnas in the northeastern part of Lazdijai District, Lithuania (Fig. 1). The soils of the western shores of the lake consist primarily of loam, while the eastern shores are sandy. The western shores are high, but those in the east are not. The lake shore eutrophication rate is 10%. Lake Dusia is a post-glacial basin with inlets and outlets. The area of the lake is 100.8 km^{-2}, which makes it Lithuania's third largest lake. The dimensions of the lake are as follows: length – 8.4 km; maximum width – 4.2 km; mean width – 2.8 km; total area – 2316.8 ha; greatest depth – 32 m; average depth – 14.6 m; shoreline length – 21.6 km; sinuosity – 1.03. There is an island (0.05 ha) in the northern part of the lake near Koja Bay. The lake has small depressions and shoals. The littoral zone is sandy and very wide, up to 100 m and more, and a narrow sandy carbonate belt stretches along the eastern shore beyond the littoral zone. The bottom of the lake is predominantly covered by clayish sediments, carbonaceous clay, and clayish silt, and in some places there are zones of carbonaceous silt (Universal Lithuanian Encyclopedia 2004).

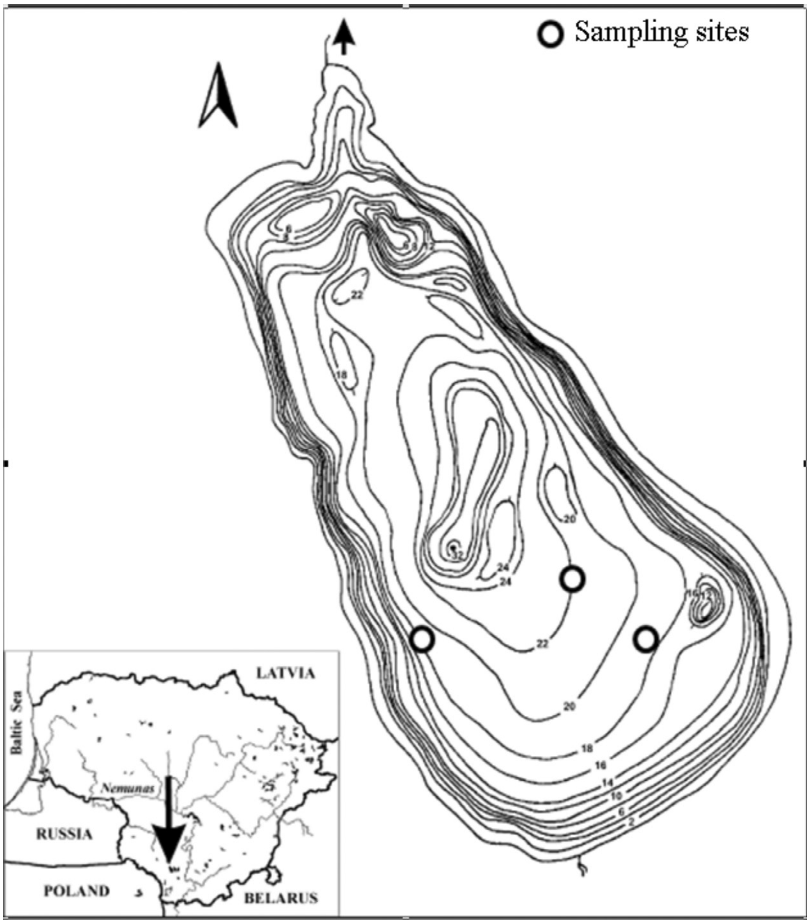

Figure 1. Sampling sites (o) of *G. cernuus* in Lake Dusia and map of Lithuania.

The water of the lake is very clear, with water transparency reaching as much as 6-6.5 m. Lake Dusia is of moderate thermal depth, and the temperature of the near-bottom water layers in the deep part of the lake reaches 10.3°C during thermal stagnation and 2.9°C in winter. In spring and fall, when water mixing is sufficient, the absolute concentrations of oxygen in the lake water are nearly the same. The water pH from the surface to the bottom ranges from 7.8 to 8.2 in winter and from 7.6-8.6 in summer. In spring and fall, pH is distributed evenly throughout the water mass. The overall water hardness from the bottom to the surface ranges from 2.6 to 3.0 mval l^{-1} in winter and 2.7 to 3.65 mval l^{-1} in summer (Universal Lithuanian Encyclopedia 2004).

Lake Dusia is mesotrophic, and according to the prevailing indicator fish species, this deep lake is classified as a type I smelt lake (Virbickas 1988, Virbickas et al. 1996). The fish community of the lake primarily comprises early succession cold-water fish, i.e. lake smelt and vendace. These dominant species are accompanied by fishes of other ecological groups, i.e., perch, ruffe, and roach.

The fish assemblage structure and the abundance of different fish species were investigated in Lake Dusia in 2007-2008. The research was conducted in October 2007 and April and August 2008. The fish were caught with 40 m gill nets with different mesh sizes (14, 18, 22, 25, 30, 40, 50, and 60 mm). The gill nets were deployed in different areas of the lake in open waters, near the shore, and at the bottom. General ichthyological analyses of the fish caught were performed by measuring fish length (TL, SL) and body weight (W) and by determining age (T). For the growth study, 250 individuals were analyzed. The diets of 150 ruffe specimens caught in Lake Dusia were also analyzed. Analysis were performed to determine abundance (N), age class (AK), age (T), and measurement (K1) structures of the populations (Thoresson 1993). The theoretical number (N) and biomass (B) of fish in the community were recalculated to area units (unit. ha^{-1} and kg ha^{-1}):

$$N = \frac{n}{pk}, \quad B = \frac{Q}{pk}$$

where n is the total number of fish caught, Q is the overall biomass of fish caught, p is the area subject to fishing, k is the catchability coefficient, which is the proportion of the fish community caught; this coefficient varies among water bodies subject to abiotic variables (Hilborn and Walters 1992).

The von Bertalanffy growth equation was used to describe growth in length:

$$Lt = L\infty[1 - e^{(-k(t-t_0))}]$$

where *Lt* is the predicted mean total length (TL in cm) of a fish of a given population at age *t, L∞* is the mean asymptotic length, i.e., the length the fish would reach at an infinitely advanced age, *k* is the coefficient of growth rate ($0< k <1$), and t_0 is the hypothetical time at which length is zero (Sparre et al. 1989). Fulton's condition factor (K) was calculated with the following formula (Ricker 1975): $K = 100 \times W \times SL^{-3}$, where body weight (W, in g) and standard length (SL, in cm) are values from the day the fish was caught. Feeding intensity was evaluated by computing stomach fullness as the percentage of body mass from: $SFI = 10000M_C W^{-1}$ where M_C is the total mass of stomach content in g, and W is the fish wet mass in g.

Age was determined using fish scales (Thoresson 1993). Fish growth rates were ranked according to species-specific growth rate groups established for Lithuanian lakes. Fish growth differs in different water bodies, which is why the main species were divided into slow-growing, moderately-growing, fast-growing, and very fast-growing groups (Stakėnas et al. 2007). The samples were analyzed at the Laboratory of Ecology and Physiology of Hydrobionts of the Nature Research Centre.

Fish stomach contents were removed from preserved fish in the laboratory, then dried on filter paper to absorb excess moisture, and weighed. Stomach contents were examined with a binocular microscope (Leica, WILD M3Z) with an additional light source (Intralux 4000). Preliminarily, stomach contents were divided according to taxonomic groups, and the weight of each group was determined. Systematic groups (type, order, family, genus, species) were identified using a binocular microscope. Finally, the individuals from each taxonomic group were counted. The data was analyzed statistically with MS Excel and Statistica 6.0.

Results

Fish community structure of Lake Dusia

At the time of the investigation, ruffe dominated in gillnet catches in the lake by abundance (64.1%), although in 2008 the relative abundance of ruffe decreased by 14.2% (from 71.2 to 57%), whereas the abundance of perch increased twice (from 15.7 to 31%). The relative abundance of roach was about 10.5%. Changes in the abundance of other fish species were insignificant. Ruffe and perch dominated the community by biomass. In the course of the year, the relative biomass of ruffe decreased 1.7-fold down to 27.6%, whereas that of perch increased 1.8-fold to 45.3%, which was the greatest share of the community. The relative biomass of roach increased significantly (1.9-fold from 13.0 to 24.9%). The biomass of pike in the community decreased from 12.1 to 2%. The total abundance of fish in the lake decreased from 3142 ind. ha^{-1} in the first year of the investigation to 2237 ind. ha^{-1} in the second, whereas biomass decreased insignificantly from 123.7 to 112.5 kg. ha^{-1}.

Growth and age structure

The means of lengths (TL and SL, cm) and masses (W, g) of different age ruffe in different seasons are presented in Table 1. The length and weight of fish of similar age varied from season to season, which was attributed to the winter of 2007/2008 which was warmer than usual, and, thus feeding conditions were favorable and this supported fish development. This is why measurements of ruffe of the same age were greater in August 2008 than in October 2007. Ruffe growth rates slow with increasing age (Table 1). Compared to published data, the growth of *G. cernuus* was rather fast (Table 2).

The theoretical growth curve for standard length is presented in Fig. 2. According to the von Bertalanffy growth equation, the length increment rate of ruffe was as follows:

$$L_t = 21.3[1 - e^{-0.161(t-0.335)}]$$

The theoretical values of body length calculated with the von Bertalanffy equation indicate high correlation with empirical data ($r = 0.975$, $P < 0.001$).

Ruffe diet

Investigations of the diet of ruffe of different age classes revealed Chironomidae to be the main food of

Table 1

Mean lengths (TL and SL, cm) and weights (W, g) of different aged *G. cernuus* in different seasons

Parameters	Date	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+
TL (cm)	October 2007	7.07±0.23	9.73±0.96	10.01±0.25	11.66±1.02	14.46±1.34	15.73±0.22	16.78±1.84	17.14±1.15	17.54±0.73	18.35±2.11
	May 2008	6.65±0.53	9.64±0.88	9.86±0.67	11.47±0.93	13.87±0.61	15.68±1.24	16.46±1.12	16.93±1.52	17.48±0.68	18.14±0.92
	August 2008	7.31±0.57	10.11±0.41	10.35±0.92	12.05±0.65	14.67±1.16	16.16±1.28	16.92±1.56	17.31±1.28	17.88±1.64	18.57±1.36
SL (cm)	October 2007	5.87±0.47	8.43±1.09	8.71±0.42	10.26±0.91	12.96±0.94	14.23±1.16	15.28±1.72	15.54±1.12	15.74±0.56	16.25±2.13
	May 2008	5.45±0.66	8.34±0.80	8.56±0.63	10.07±0.82	12.37±0.52	14.08±1.03	14.86±0.95	15.23±1.37	15.58±0.69	15.94±0.86
	August 2008	6.01±0.49	8.81±0.38	8.95±0.87	10.65±0.53	13.17±1.06	14.56±1.26	15.32±0.87	15.51±1.08	15.98±1.54	16.37±1.24
W (g)	October 2007	6.51±0.72	10.15±1.29	13.72±0.41	20.60±2.17	33.08±2.04	40.67±1.78	46.58±2.25	68.01±1.45	67.06±1.27	73.66±2.01
	May 2008	6.40±0.32	10.06±0.86	13.54±0.21	19.88±1.33	31.30±1.19	37.06±0.78	41.62±1.39	67.04±2.16	69.40±1.43	74.17±2.44
	August 2008	7.14±0.28	11.67±0.46	14.91±0.61	23.70±0.57	34.84±0.98	44.29±1.46	49.13±1.53	70.15±1.98	71.09±2.12	76.18±2.31

Table 2

Total lengths at age of *G. cernuus* populations and comparisons with the results of the present study

Study site (country)	1+	2+	3+	4+	5+	6+	7+	Reference
Lake Dusia (Lithuania)		6.6	9.3	9.9	11.2	13.0	15.8	present study
Curonian Lagoon (Lithuania)	5.5	7.5	9.3	10.3	11.7			Titova (2007)
Kaunas Reservoir (Lithuania)	5.3	7.9	10.2	10.8	12.6	13.8	15.0	Dautartas (1983)
Lake Drysviaty (Belarus)	4.3	6.6	9.5	11.9	11.9			Kybartaitė (1961)
Lake Dysnai (Lithuania)	4.9	6.1	8.4					Subatavičiūtė (1960)
Lake Mildevatn (Norway)	3.5	5.6	7.1	7.8	8.0	8.2	9.1	Kalas (1995)
Lake Piediluco (Italy)	7.8	11.6	13.3	14.2				Lorenzoni et al. (2009)
Lake Vortsjarv (Estonia)	4.2	6.9	7.8	9.1				Kangur et al. (2003)
Lake Peipsi (Estonia)	5.3	6.8	8.1	8.7				Kangur et al. (2003)
Lake Oron (Russia)			8.0	10.4	11.2	12.4	13.4	Jurev (2007)

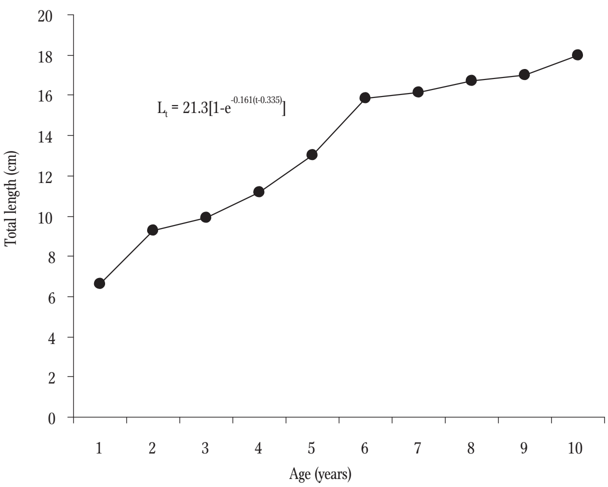

Figure 2. Von Bertalanffy's growth curve of G. cernuus in Lake Dusia.

young ruffe aged 2+ and 3+ years (Fig. 3). The stomach contents of some individuals aged 2+ also contained Daphnia. From about ≥ 4+ years of age, depending on the season, ruffe preferred crustaceans (Gamaridae) or molluscs (*Viviparus viviparus*). The stomach contents of older ruffe also contained spawn and caddisflies. Seasonality was not found to significantly affect the ruffe diet, but slightly higher diet versatility was noted in summer compared with the other seasons (Fig. 3).

Ruffe aged from 6+ to 9+ fed more intensively, but intensity started to decline from age 7+. We found that stomach fullness in October 2007 was somewhat lesser than in May and August 2008. Fulton's condition factor showed that best condition of 2+ ruffe was in May 2008 (Fig. 4).

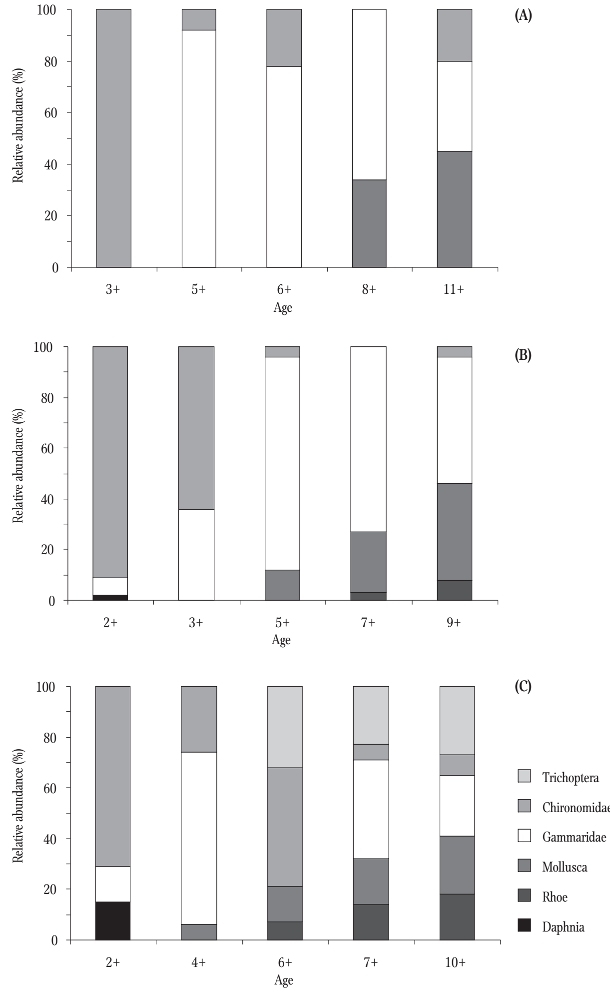

Figure 3. Seasonal changes in diet of *G. cernuus* from Lake Dusia. A – spring, B – summer, C – fall.

Discussion

Chironomidae and Crustacea were the main diet components of immature and mature ruffe. Among Chironomidae, *Chironomus* and *Procladius* were the most preferred. The prevalence of chironomids in the ruffe diet declined with age as the size of the fish increased. Ephemeroptera, Trichoptera, and Hirudinea were the other macrobenthos that dominated the diet. Juvenile ruffe usually feed on Chironomidae, although some authors report that microcrustaceans are the main food for ruffe measuring 5 cm (Boron and Kuklinska 1987). Ruffe have also been observed foraging *Pallasea quadrispinosa*, *Pontoporeia afflnis*, *Mysis relicta*, *Neomysis integer*, and *Gammarus spp.* (Ogle 1998). According to Johnsen (1965), *Asellus*, *Gammarus*, *Dytyscus* larvae, and *Pisidium* are the main ruffe food. Lind (1977) states that in rivers with weak currents, Chironomidae caterpillars and larvae are the main ruffe food; however, they also prey on caddisflies (Trichoptera), *Corophium*, *Gammarus*, and other larvae as well as small Malocostraca when present. Orlova and Popova (1986) report

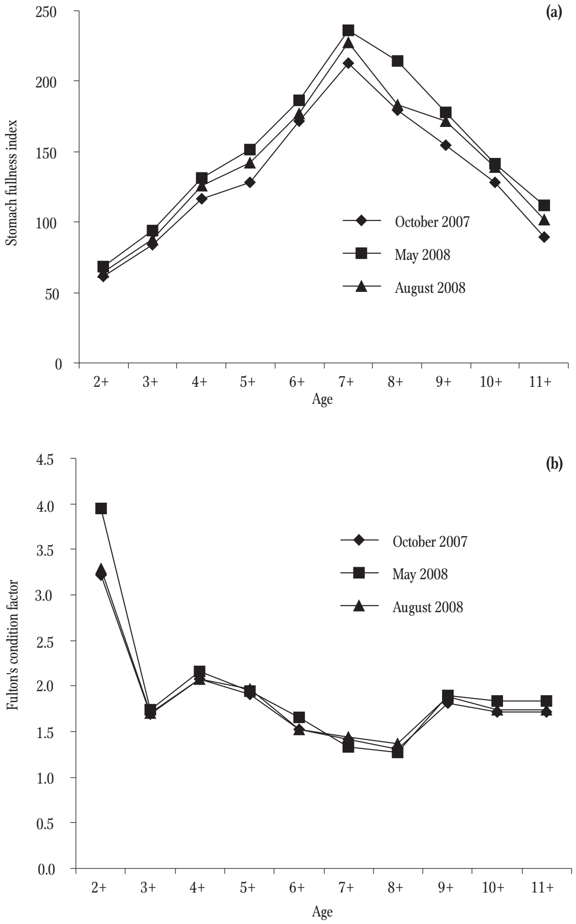

Figure 4. Stomach fullness indexes (a) and Fulton's condition factor (b) estimated for individual *G. cernuus* in Lake Dusia.

Chironomus and *Asellus* as the main food of ruffe. Sabaneev (1911) noted that in spring ruffe feed on the spawn and juveniles of other fish species, and, therefore, they have a detrimental effect on other fish species in small lakes.

The present results demonstrate that the ruffe diet changed over the course of the lifespan of this species, and included ontogenetic diet shifts and size-dependent variations in diet partitioning. In lakes with moderate and high productivity, ruffe preferred Chironomidae and Ephemeroptera, although diet versatility was observed to increase as lake productivity increased. Boikova (1986) reported similar dietary changes in ruffe 8-10 cm in length, while other authors (Ogle et al. 1995, Ogle 1998) registered similar changes in ruffe of 12 cm. Young and mature ruffe can feed on Chironomidae, Ephemeroptera, and *Sialis* spp., but they often choose Oligochetae and Hirudinea (Bergman and Greenberg 1994, Ogle 1998). For example, ruffe juveniles feed most frequently on *Daphnia* and *Copepoda*. On the contrary, Kangur et al. (2003) states that the amount of *Chironomus plumosus* consumed by ruffe is in direct proportion to the abundance of *Ch. plumosus* in the benthos, i.e. the more abundant *Ch. plumosus* is in a water body, the more often ruffe consumes it. Bergman and Greenberg (1994) showed that the dietary ontogeny of perch can be altered by competition with ruffe. Ruffe and perch compete for food resources, and increased ruffe density changes roach density prompting perch to eat more zooplankton, which decreases its growth (Bergman 1990). Ruffe is not well studied in Lithuania. This species is not fished commercially in inland waters; however, results from earlier investigations conducted in 1951-1957 and 1993-1995 indicate they compete for food with many benthophagous fishes (Kublickas 1959, Virbickas et al. 1996). Chironomidae, in particular *Ch. plumosus,* are a year-round dominant in the ruffe diet in the Curonian Lagoon. The maximum number of chironomids is recorded in March (100%). Their numbers start to decrease gradually in April until the minimum is reached in July. A change in the amount of chironomid larvae in benthos affected the ruffe diet. In summer, ruffe shifted from chironomids to fish, caddisflies, benthic and planktonic crustaceans, and leeches. Ruffe forages intensively nearly year round, even in winter and during spawning (Kublickas 1959).

In the artificial Lake Kauno Marios, the diet of mature ruffe consists mainly of chironomids (97.3%). The most intensive foraging is observed in summer and fall (Jablonskis 1981, Dautartas 1983). In Lake Drūkšiai, ruffe aged 1+ to 3+ feed predominantly on *Cladocera* and *Copepoda* in March and shift to chironomid larvae in May. According to the stomach fullness index, ruffe aged 4+ and 5+ feed most intensively in April, while in May their feeding intensity begins to decline until the minimum is reached in July. According to the fatness index, the feeding intensity of ruffe aged 3+ and 4+ gradually decreases as does their fatness, whereas the stomach fullness index of ruffe aged 2+ increases, and, thus, fish fatness increases (Kybartaitë 1961). The ruffe of Lake Dysnai exhibit the most intensive feeding in June, with tendipedids, caddisflies, and mayflies being the main components of their diet (Subatavičiūtė 1960). Similar tendencies are observed in other regions. For example, in Lake Piediluco (Italy), the length and weight of ruffe increases throughout the year, but their growth increases in spring and slows in summer. The growth rate begins to decline from age 4+. Both males and females mature at the age of 1+ (Lorenzoni et al. 2009); however, growth rates vary among different water bodies. For instance, in Lake Drysviaty (Belarus) ruffe length ranges from 3.7 to 12.2 cm, and catches were dominated by ruffe measuring 6.5 to 9.5 cm (Kybartaitė 1961). In Lake Dysnos, the largest ruffe caught were 10.3 cm in absolute length, and the mean total value of lengths was 5.9 cm; however, only individuals aged 1+, 2+, and 3+ were caught (Subatavičiūtė 1960). In lakes Vortsjarv and Peipsi in Estonia, the mean total length of ruffe was 6.8 cm and 8.7 cm, respectively, while the largest ruffe caught in these lakes were 12.5 cm and 14.8 cm long, respectively (Kangur et al. 2003). The mean ruffe length was just 9.3 cm in Lake Mildevatn (Norway) (Kalas 1995), it ranged from 8.0 to 14.3 cm in Lake Orono (Russia) (Jurev 2007), and it reached as much as 14.8 cm in Lake Piediluco (Italy) (Lorenzoni et al. 2009).

The growth observed in Lake Dusia was close to the best reported in other lakes. It was similar to that of Lake Drysviaty (Belarus), but lower than that noted in the Curronian Lagoon (Lithuania) and Lake Piediluco (Italy). Obviously, ruffe growth rates are faster in southern areas as compared to those in the north. In conclusion, this study provides detailed estimates of diet, age, and growth of *G. cernuus*, which can be used to improve the management and conservation of native populations of fish in Lake Dusia and to understand the ecological response of ruffe.

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Author contributions. A.P. and V.K. designed and performed the investigations in all seasons in Lake Dusia; A.P. and E.B. analyzed the data. All of the authors participated in hypothesizing the main concepts of the research. L.Č. and A.P. Were responsible for the statistical analysis of the data ; L.Č. wrote the paper.

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